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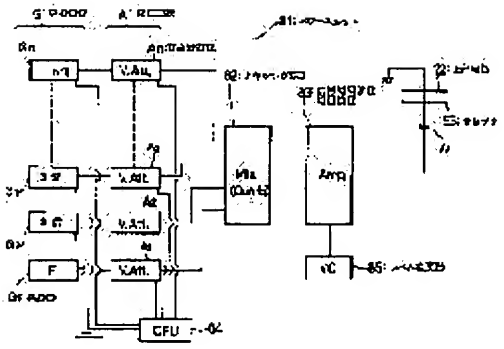
(54) PLASMA PROCESSING METHOD

(57)Abstract:

PURPOSE: To prevent a semiconductor wafer from charging up and to improve the etching rate in etching a semiconductor wafer under an atmosphere of plasma in the processing chamber.

CONSTITUTION: An oscillator G1 generating a fundamental wave, oscillators G2-Gn generating waves of integral multiples of the fundamental wave frequency, and variable attenuators A1-An corresponding to each of the oscillators G1-Gn are used to compose output waveforms of these for frequency modulation and impressed on a susceptor 55 which is a lower electrode. Depending on the output waveform, progress of a plasma dissociation stage is controlled to prevent the excessive generation of incident ions, and further, acceleration of incident ions can be controlled.



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* NOTICES *

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2.**** shows the word which can not be translated.
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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] this invention relates to the plasma treatment method.
[0002]
[Description of the Prior Art] When making the processing interior of a room airtightly constituted in the magnetron RIE system generate the plasma by impression of RF power and performing etching processing from the former to the processed object, for example, the semiconductor wafer etc., of the processing interior of a room concerned etc. in this plasma atmosphere, for example, in order to raise plasma density and to raise an etching rate, it was made for the many to impress the RF power whose frequency is 13.56MHz by AC power supply.
[0003]
[Problem(s) to be Solved by the Invention] However, when the RF power of frequency single such was impressed, electrification which inclined toward the front face of the above-mentioned semiconductor wafer by the electron with high mobility in the above-mentioned magnetron RIE system occurred, the inclination of potential arose, and there was a possibility of as a result leading to the device destruction by the charge up, for example.
[0004] Then, although a certain means for preventing such a charge up is needed, I hear that that it must mind in that case must prevent the charge up concerned, without reducing an etching rate, and there is.
[0005] this invention is made in view of such a trouble, and it sets it as the 1st purpose to offer the new plasma treatment method of preventing the above charge ups, without reducing plasma density.
[0006] By the way, in the plasma treatment equipment using high-density plasma, such as a magnetron RIE system, efficient consumer response plasma equipment, etc. which were described above, for example, if the RF power of frequency single like the above-mentioned is impressed, still more nearly another problem will arise. For example, when etching the oxide film to Si of a substrate to the semiconductor wafer which is a processed object, using CF4 gas as a raw gas, since the energy absorbed by plasma is high, with said high-density plasma, the maceration of a gas molecule progresses greatly, by the case where it is CF4, it will progress to the maceration of a culmination and, as for a radical component, the most will become F* (fluorine radical).
[0007] Therefore, there was a problem that the etching resistance of protection polymer will fall sharply and a selection ratio will fall as a result. Moreover, when it progressed to the maceration of a culmination, a lot of C occurred and it had also produced the problem that will carry out a deposition to a wafer front face, and the etching itself will be stopped. And with the alternating current RF power which has single sinusoidal type, control of such maceration is difficult.
[0008] this invention makes it the 2nd purpose to raise the selection ratio in etching etc. by being made also in view of such a point, for example, making the processing interior of a room generate plasma, and adding a modulation to the aforementioned RF power in the method of processing under the aforementioned plasma atmosphere to the processed object of the processing interior of a room concerned, with RF power.

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[0009]
[Means for Solving the Problem] Like a ** top, the charge up generated on processed objects, such as a semiconductor wafer, has a cause in only an electron with high mobility being moved and charged by impression of RF power. Then, in order for artificers to do to neutralizing the electron charged such by the ion of the processing interior of a room and to move such ion on a processed object, the technique of making low frequency power impress was taken.
[0010] However, only by replacing with RF power and impressing low frequency power, plasma density falls, an etching rate also falls and there is a problem practically. Therefore, in this invention, the modulation by low frequency power is partially added to RF power so that an etching rate may not be reduced, and solution of the above-mentioned problem is aimed at.
[0011] When it talks about concrete composition, in a claim 1, the plasma treatment method which the processing interior of a room is made to generate plasma with RF power, and is characterized by adding frequency modulation by low frequency power to the aforementioned RF power in the method of processing to the processed object of the processing interior of a room concerned is offered. In this case, you may make it apply low frequency power by amplitude modulation, as indicated to the claim 2.
[0012] In addition, although, as for RF power, the frequency with sufficient dissociation efficiency of plasma says a thing 10MHz or more and low frequency power says for convenience that to which frequency does not exceed the 10MHz concerned in this invention, 3MHz or less, the frequency of the low frequency power applied by the modulation in the aforementioned claims 1 and 2 is divided, and a thing 2MHz or less is desirable [frequency] also in it.
[0013] Moreover, according to [for the 2nd purpose achievement] the claim 3, the processing interior of a room is made to generate plasma using said power in which the direction of current carries out aging, and the plasma-treatment method characterized by to add frequency modulation to the power which has fundamental frequency with the fundamental frequency n times (n= integer) the frequency of being concerned is offered in the method of processing under the aforementioned plasma atmosphere to the processed object of the processing interior of a room concerned.
[0014] In the method of making the processing interior of a room generating plasma using the power in which the direction of current carries out aging according to the claim 4 furthermore, and processing under the aforementioned plasma atmosphere to the processed object of the processing interior of a room concerned, the power which has fundamental frequency is provided with the plasma-treatment method characterized by to add frequency modulation with two or more frequency which it is, and is mutually different. [of this] [n times / which is the fundamental frequency concerned / (n= integer)]
[0015] In each of these plasma treatment methods, as indicated to the claim 5, the reactant gas introduced into the aforementioned processing interior of a room may constitute so that maceration of a culmination may not be started by the generated plasma, and the aforementioned frequency modulation may be controlled.
[0016] Furthermore by the claim 6, the plasma treatment method which the processing interior of a room is made to generate plasma with RF power, divides signalling frequency in period in the method of processing under the aforementioned plasma atmosphere to the processed object of the processing interior of a room concerned, and is characterized by adding frequency modulation is offered.
[0017] Moreover, according to the claim 7, make the processing interior of a room generate plasma with RF power, and it sets to the method of processing under the aforementioned plasma atmosphere to the processed object of the processing interior of a room concerned. Add amplitude modulation to the aforementioned RF power, and are called the envelope obtained as a result. The plasma treatment method characterized by falling with the standup section of a subcarrier form which connected the peak of the modulated wave and was obtained, and making it the time of the section become below 10microsec. (second), respectively is offered.
[0018]
[Function] The ion and electron transfer in plasma are performed with change of alternating current electric field. Therefore, charge on processed objects, such as a wafer, can be canceled by movement of ion, without reducing plasma density, if the low frequency power with which ion with large mass can

follow in footsteps is partially applied to the RF power with sufficient dissociation efficiency of plasma and it is made to modulate it (neutralization).
[0019] Without extinguishing the dissociation state generated by then, when etching is promoted and the modulation by low frequency power is added, while in the case of frequency modulation indicated to the claim 1 the operation by RF power and low frequency power was obtained independently by time, for example, RF power was impressed, ion moves, it neutralizes with the electron on a processed object, and, as a result, charge is canceled.
[0020] Although in the case of the amplitude modulation indicated to the claim 2 on the other hand it is impressed after RF power and low frequency power have lapped, the above-mentioned counteraction by low frequency is obtained simultaneously, maintaining the plasma state before adding a modulation as it is.
[0021] Moreover, what is necessary is just to judge the timing which adds the respectively above modulations in claims 1 and 2 based on the value of the charge-up voltage generated on a processed object.
[0022] By the way, the mode changes with waves of the electrical signal movement of the ion in the generated plasma and whose incidence to the processed object which especially influences processing of etching etc. directly are energy sources. For example, according to the old sine wave, acceleration is not fixed, therefore control of the dissociation stage of the raw-gas molecule introduced into the processing interior of a room is difficult like previous statement.
[0023] Since maceration does not progress in the flat part in the wave, the pulse wave from which this point, for example, a predetermined interval, is set, and fixed time and a fixed output are obtained For example, it is possible to adjust a dissociation stage by adjusting pulse width. Moreover, since a SOUTUSU wave (saw-tooth wave) and a triangle wave (triangular wave) with the fixed inclination of the falling section, and a RAMUPU wave (ramp) have fixed acceleration, The ion bombardment (ion bombardment) of etchant ion can be enlarged, and it is possible to raise an etching rate as a result.
[0024] In the method of making the processing interior of a room generating plasma under this background [like] using the power in which the direction of current carries out aging according to the claim 3, and processing under the aforementioned plasma atmosphere to the processed object of the processing interior of a room concerned For example, since frequency modulation is added to the power which has arbitrary fundamental frequency including 380kHz with the fundamental frequency n times (n= natural number) the frequency of being concerned, the power for plasma generating which has a different wave from a mere single sine wave can be obtained. Therefore, it becomes possible to control ion bombardment of etchant ion based on the wave concerned.
[0025] Since frequency modulation is added with two or more frequency which has n times (n= integer) of the aforementioned fundamental frequency, and is mutually different according to this point claim 4, SOUTUSU waves (saw-tooth wave) including said pulse wave, a triangle wave (triangular wave), and a RAMUPU wave (ramp) can be made to create easily.
[0026] Moreover, since it was made to control frequency modulation by the claim 5 so that the reactant gas more concretely introduced into the processing interior of a room did not start the maceration of a culmination in the plasma treatment method of these claims 3 and 4, superfluous etchant ion cannot be generated and a selection ratio can be raised.
[0027] Furthermore, since it is carrying out for dividing signalling frequency in period and adding frequency modulation, the maceration of the raw-gas molecule introduced into the processing interior of a room in the portion with high frequency can be promoted, or an ion bombardment can be enlarged in a portion with low frequency at a claim 6. And since in this case signalling frequency is divided for every several periodic unit, for example, half period, one period, and round term or several round term and frequency modulation is added, high control of a minute precision is attained.
[0028] Moreover, since according to the claim 7 it is constituted so that amplitude modulation may be added to RF power, it may fall with the standup section in the envelope obtained as a result and the time of the section may become below 10microsec. (second), for example in etching processing, it is directly shorter than the dissociation reaction time of the gas molecule in connection with an etching reaction,

and maceration of the aforementioned gas molecule is not advanced in these portions. Therefore, since it can fall with these standup section and maceration can be controlled by the remaining portion except the section, it is easy to control.

[0029]

[Example] The composition of magnetron RIE system 1 used when the example of this invention was explained based on the drawing, and drawing 1 carried out the 1st example is shown typically hereafter, and this magnetron RIE system 1 has the processing room 2 which is the airtight container which consisted of the quality of the materials, such as aluminum, and was grounded electrically.

[0030] The exhaust pipe 5 which leads to the exhaust air meanses 4, such as a vacuum pump, is connected to the exhaust port 3 prepared in the bottom in the aforementioned processing room 2, and vacuum length of the inside of the aforementioned processing room 2 is equally carried out from the bottom periphery by this exhaust air means 4, and it is constituted by the any value between predetermined reduced pressure atmosphere, for example, the range of Number mTorr - dozens Torr(s), so that setting maintenance may be possible.

[0031] The susceptor susceptor 7 is formed in the center of a bottom in the aforementioned processing room 2 through the electric insulating plates 6, such as a ceramic, and the susceptor 8 which consists of the quality of the materials, such as aluminum, and constitutes a lower electrode is further formed in the upper surface of this susceptor susceptor 7. It is constituted so that the ** tone refrigerant which the refrigerant room 9 is formed in the interior of the aforementioned susceptor susceptor 7, and is introduced in this refrigerant room 9 from the refrigerant introduction pipe 10 formed in the bottom of the above-mentioned processing room 2, and is discharged from the refrigerant exhaust pipe 11 may circulate, and the above-mentioned susceptor 8 is controlled to desired temperature.

[0032] RF generator 21 and the low frequency power supply 22 are formed in the exterior of the above-mentioned processing room 2. This RF generator 21 is constituted so that frequency, such as 13.56 etc.MHz, may output RF power 10MHz or more, and on the other hand, the 2 etc.MHz of the above-mentioned low frequency power supplies 22 etc. is constituted so that the power of low frequency may be outputted to the relative target whose frequency is 100kHz - 3MHz. And the power from each above-mentioned RF generator 21 and the low frequency power supply 22 is once inputted into a modulator 23, it is constituted so that frequency modulation may become free by the operation of this modulator 23, and it is constituted so that it may be impressed by the above-mentioned susceptor 8 through the blocking capacitor 24 after that.

[0033] each above-mentioned RF generator 21, the low frequency power supply 22, and a modulator 23 are constituted so that it may be controlled by the controller 25, and they impress only the RF power from RF generator 21 to the above-mentioned susceptor 8, for example by the ordinary state by this controller 25 -- as -- controlling -- every fixed time -- the low frequency power from the low frequency power supply 22 -- the RF power from above-mentioned RF generator 21 -- a predetermined time -- in addition, it is constituted so that frequency modulation may be carried out

[0034] The electrostatic chuck 31 by which the semiconductor wafer W which is a processed object is laid directly, and suction maintenance is carried out is formed in the upper surface of the above-mentioned susceptor 8. If it has the composition pasted up on both sides of the conductive layer 32 which consists of electric-field **** with insulators, such as a polyimide film, from vertical both sides and, as for this electrostatic chuck 31, direct current voltage is impressed to the above-mentioned conductive layer 32 by the high-voltage-direct-current power supply 33 prepared in the processing room 2 above-mentioned exteriors, suction maintenance of the above-mentioned semiconductor wafer W will be carried out by the Coulomb force at the above-mentioned electrostatic chuck 31.

[0035] On the other hand, the up electrode 42 electrically grounded through the grounding conductor 41 is formed in the upper part in the above-mentioned processing room 2. an opposed face with the above-mentioned semiconductor wafer [in / this up electrode 42 / further / besides the section electrode 42 has hollow structure which consists of for example, amorphous carbon, aluminum by which SiC surface treatment was carried out, and] W -- many gaseous diffusion -- the hole 43 is formed and raw gases, such as etching gas which the gas inlet 45 which leads to the raw-gas introduction pipe 44 is formed

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focusing on the upper part of the up electrode 42, and is supplied from the above-mentioned raw-gas introduction pipe 44, -- the gaseous diffusion of the above-mentioned gas inlet 45 to above-mentioned a large number -- through the hole 43, it is constituted so that it may be equally breathed out towards the above-mentioned semiconductor wafer W

[0036] And the upper surface of the up electrode 42 as stated above is approached with this, and the permanent magnet 46 is arranged on it. this permanent magnet 46 is constituted so that the above-mentioned raw-gas introduction pipe 44 may be rotated as the center-of-rotation shaft with a desired rotational speed with drives (not shown), such as a motor, -- having -- **** -- the above -- it is possible to form an almost uniform parallel magnetic field, for example, the magnetic field of the any value between the ranges of 10-1000G, in the front face to the semiconductor wafer W laid on the electrostatic chuck 31

[0037] Magnetron RIE system 1 used in order to carry out this example is constituted as mentioned above, and if the case where it etches to the semiconductor wafer W by this magnetron RIE system 1 is explained, the semiconductor wafer W which serves as an etching processing object first will be carried in in the processing room 2 from the load lock chamber (not shown) established in this magnetron RIE system 1 through the gate valve (not shown), and will be laid on the electrostatic chuck 31. And adsorption maintenance of the above-mentioned semiconductor wafer W is carried out by impression of the high-voltage-direct-current power supply 33 on this electrostatic chuck 31.

[0038] The inside of the after-treatment room 2 is exhausted by the exhaust air means 4, and, on the other hand, etching reactant gas, for example, CF4 gas, is supplied in the processing room 2 from a gas inlet 45, and the pressure in the processing room 2 is set up and maintained by for example, 10mTorr(s). And a magnetic field is applied so that the rotation drive of the permanent magnet 46 may be carried out and the magnetic field of 100G may be formed near [above-mentioned] a semiconductor wafer W core.

[0039] On the other hand, by directions of a controller 25, 13.56MHz RF power is first impressed to a susceptor 8 from RF generator 21 as it is to the above-mentioned semiconductor wafer W, plasma occurs in the processing room 2, and anisotropic etching by the reactant ion accelerated in the sheath layer is performed to the above-mentioned semiconductor wafer W.

[0040] by the way -- if the inclination of potential occurs on the above-mentioned semiconductor wafer W and impression by the above-mentioned RF power which is 13.56MHz is continued as it is, as it was shown in drawing 2 , when etching by the 13.56 above-mentionedMHz RF was performed as it is -- just -- being alike -- there is a possibility that destruction of the device by the charge up may occur

[0041] Then, in order to prevent such a charge up beforehand, frequency modulation of the low frequency from the low frequency power supply 22, for example, the 2MHz low frequency power, is applied and carried out to 13.56MHz RF power by the modulator 24 from above-mentioned RF generator 21 with directions of the above-mentioned controller 25.

[0042] In this case, when the above-mentioned charge voltage for example, on the semiconductor wafer W (E in drawing 2) arrives at the 10V neighborhood, as for the timing which adds the above-mentioned modulation, it is desirable to become irregular preferably at the time of 5V. Generally the device destruction by this kind of charge up is because it will generate in many cases if it becomes more than 10V. However, this voltage cannot be overemphasized by changing with structures of a device. Therefore, if the modulation by the 2MHz above low frequency power is added in the stage before it, neutralization by movement of ion will be performed, charge will be canceled on the above-mentioned semiconductor wafer W, and the destruction by the charge up will be prevented beforehand.

[0043] In addition, the judgment at the time of the above-mentioned charge voltage on the semiconductor wafer W amounting to 10V or 5V such For example, the charge voltage on the dummy wafer concerned at the time of **********ing on the same conditions using a dummy wafer is measured. The time when amounting to 10V or 5V such is recorded as data, the recorded data concerned are stored in the above-mentioned controller 25, and you may make it make it become irregular based on it. And what is necessary is to stop a modulation again and just to make etching continue by impression of the 13.56MHz RF power from above-mentioned RF generator 21, after becoming irregular such fixed

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time. These control is performed by the controller 25.
[0044] What is necessary is to repeat the modulation by the modulator 23 again and just to go, when the above-mentioned charge voltage amounts to 10V or 5V again by etching end as mentioned above. By doing in this way, the device destruction by the charge up of the semiconductor wafer W which is a processed object is prevented. And since the modulation by low frequency power does not almost reduce plasma density by line crack's only when charge voltage amounts to 10V, an etching rate does not fall.
[0045] In addition, although two power supplies, RF generator 21 and the low frequency power supply 22, were used in the 1st example of the above, in the case of frequency modulation, the power unit of 1 is used, for example, you may make it switch frequency to a RF and low frequency suitably by control of the above-mentioned controller 25.
[0046] In addition, although the modulator 23 in the 1st example of the above was constituted so that frequency modulation might be performed, even if it performs the modulation by amplitude modulation using the modulator which performs not only this but amplitude modulation, the same effect as the above is acquired.
[0047] Moreover, although the plasma treatment equipment used in the 1st example of the above was a magnetron RIE system, not only this but this invention is applicable to various kinds of plasma equipments which fear of a charge up produces on a processed object in the case of plasma treatment.
[0048] Next, the 2nd example is explained. the cross section of the plasma etching system 51 used in order that drawing 3 might carry out the 2nd example -- typical -- being shown -- **** -- this plasma etching system 51 -- the above -- it differs in magnetron RIE system 1 used on the occasion of the 1st example, and is constituted as the so-called parallel monotonous type RIE system
[0049] a plasma etching system 51 -- the above -- like magnetron RIE system 1 For example, have the processing room 52 fabricated the shape of a cylinder or a rectangle which a front face becomes from the aluminum by which oxidization alumite processing was carried out, and the electric insulating plates 3, such as a ceramic, are minded [of this processing room 52]. The susceptor susceptor 54 of the shape of an approximate circle pillar for laying the processed object W, for example, a semiconductor wafer, is held, and the susceptor 55 which constitutes a lower electrode is further formed in the upper part of this susceptor susceptor 54.
[0050] The refrigerant room 56 is established in the interior of the above-mentioned susceptor susceptor 54. The refrigerant for temperature control, such as liquid nitrogen, can introduce into this refrigerant room 56 through the refrigerant introduction pipe 57. It is possible to cool, for example to the temperature which refrigerants, such as liquid nitrogen, circulate through the inside of this refrigerant room 56, carries out heat transfer of the introduced cold energy which is produced in the meantime from the refrigerant room 56 to the semiconductor wafer W through a susceptor 55, and asks for the processing side of the semiconductor wafer W. In addition, when liquid nitrogen is used as a refrigerant, for example, the nitrogen gas produced according to the nucleate boiling is discharged out of the processing room 52 from the refrigerant exhaust pipe 58.
[0051] The above-mentioned susceptor 55 is fabricated by disc-like [convex in a upper-limit center section]. in the center The isomorphous electrostatic chuck 61 is formed and the conductive layer 62 between the macromolecule polyimide films of two sheets is received. the above -- the semiconductor wafer W which is an equipment processed object like magnetron RIE system 1, and abbreviation -- From the direct-current high voltage power supply 63 currently installed in the processing room 52 exteriors, adsorption maintenance of the semiconductor wafer W laid in this electrostatic chuck 62 upper surface is carried out by impressing the 1.5kV direct-current high voltage, for example in the position.
[0052] The gas passageway 64 for penetrating these and supplying heat transfer gas, such as helium, to the rear face of the semiconductor wafer W is formed in the above-mentioned susceptor susceptor 54, the susceptor 55, and the electrostatic chuck 61, and it is constituted so that it may be possible to make predetermined processing temperature set up and maintain this semiconductor wafer W that is a processed object.
[0053] The annular focal ring 65 is arranged at the upper-limit periphery section of the above-mentioned susceptor 55 so that the semiconductor wafer W laid on the electrostatic chuck 61 may be surrounded.

from the insulating quality of the material this focal ring 65 does not draw reactant ion near to which -- becoming -- plasma -- it is constituted so that incidence of the generated reactant ion may be effectively carried out to the semiconductor wafer W of the inside

[0054] It counters above the above-mentioned susceptor 55 in parallel with this susceptor 55. From this, it is made to estrange about about 15-20mm, and the up electrode 72 grounded by the grounding conductor 71 is formed in the position. for example, etching reactant gas, such as CF4 pass a centrum 74 from the raw-gas introduction pipe 73 besides located at the center of the section electrode 72 -- gaseous diffusion -- it is constituted so that it may be equally breathed out from a hole 75 to the aforementioned semiconductor wafer W

[0055] While the exhaust pipe 76 is connected to the side-attachment-wall lower part of the above-mentioned processing room 52, and being constituted so that the vacuum length of the inside of this processing room 52 may be carried out by exhaust-air meanses (not shown), such as a turbo molecular pump, the gate valve (not shown) which can be freely opened and closed in a side-attachment-wall center section is prepared, and the semiconductor wafer W which is a processed object is constituted through this gate valve so that carrying-in taking out may be carried out by conveyance meanses (not shown), such as a conveyance arm

[0056] and the above -- it is constituted so that the power from a power unit 81 with which the detail was shown in drawing 4 may be impressed to a susceptor 55 through the blocking capacitor 77 The oscillation equipment G with which this power unit 81 consisted of fundamental-wave VCO G1 which oscillates a fundamental wave, for example, a sine wave with the frequency of 380kHz, and two or more VCO G2-Gn which oscillates the sine wave of the frequency of the integral multiple of the aforementioned fundamental wave The absorber A which consisted of variable attenuators A1-An prepared respectively corresponding to each aforementioned VCO G1-Gn It has the mixing equipment (or combined-harvester-and-thresher equipment) 82 which mixes the output signal from each variable attenuators A1-An in these absorbers A, and the wide band frequency amplifying device 83 for amplifying the output signal of this mixing equipment 82.

[0057] Each attenuance of each VCO which each aforementioned VCO G1-Gn and variable attenuators A1-An were controlled by the central control unit 84, and the arbitrary VCO in each VCO G1-Gn was put together, operated, and operated further is adjusted individually, respectively, and each of these output signals are constituted so that it may be inputted into mixing equipment 82. and each signal from each variable attenuators A1-An inputted into mixing equipment 82 is compounded, and is further amplified with the wide band frequency amplifying device 83 -- having -- as the power for plasma generating -- the above -- it is impressed by the susceptor 55 in the processing room 52 In addition, the level change machine 85 is separately formed in the aforementioned wide band frequency amplifying device 83, and it is possible to adjust arbitrarily change of the level of the wave impressed to a susceptor 55.

[0058] If the plasma etching system 51 for carrying out the 2nd example is constituted as mentioned above and the operation etc. is explained below It is completely the same as that of magnetron RIE system 1 used in the 1st example. fundamental carrying-in operation into the processing room 52 of the semiconductor wafer W whose case of this plasma etching system 51 is also a processed object -- the above -- It is carried in in the processing room 52 from the load lock chamber (not shown) first prepared through the gate valve (not shown), and is laid on the electrostatic chuck 61. And adsorption maintenance of the above-mentioned semiconductor wafer W is carried out by impression of the high-voltage-direct-current power supply 63 on this electrostatic chuck 61.

[0059] the inside of the after-treatment room 52 is exhausted by the exhaust air means -- having -- moreover -- on the other hand -- gaseous diffusion -- etching reactant gas, for example, CF4 gas, is supplied in the processing room 52 from a hole 75, and the pressure in the processing room 52 is set up and maintained by for example, 10mTorr(s) And although predetermined power is impressed to the aforementioned susceptor 55 from a power unit 81, generate plasma between the up electrode 72 and a susceptor 55, the CF4 aforementioned gas is made to dissociate and predetermined etching processing is performed to the semiconductor wafer W which is a processed object Since the aforementioned power

unit 81 has the composition shown in drawing 4 like previous statement, it can control the maceration which performed frequency modulation to the aforementioned power which carries out impression, was made to create the wave which was most suitable for each etching processing, and was described above by this.

[0060] For example, if it explains taking the case of etching of the silicon oxide using CF4 for forming a contact hole in a semiconductor wafer W front face, CF4 gas molecule excited by plasma will start the maceration of a multi-stage story as follows in plasma.

[0061] That is, CF4 is dissociated like -CF3 F- CF3+ + and F + e-, F- becomes F- -> F* + e- and this F* (fluorine radical) etches to SiO2 of a wafer W front face. + F- CF3- + -F CF3+ +

[0062] According to the conventional high-density plasma by this point and the single sine wave, said maceration will advance to a culmination, a fluorine radical will be generated superfluously, into protection polymer, F mixed, etching resistance fell, and the selection ratio of the oxide film to Si had fallen.

[0063] However, according to the power unit 81 of said plasma etching system 51, it is possible to be able to make into arbitrary things the wave of the power made to impress to the aforementioned susceptor 55, and to acquire the optimal output wave according to the purpose by frequency modulation. A fundamental wave F (for example, 380kHz) is oscillated from VCO G1. for example, from the VCO after other VCO G2 As the frequency of the integral multiple of the fundamental wave F concerned, for example, a double-precision wave, (760kHz), a 3 time wave (1140kHz), a 4 time wave (1520kHz), and ... are oscillated, for example, it was shown in drawing 5 If 180 degrees of phases can be shifted about the output of a wave even times, it is a phase as it is about a wave, these are adjusted by each variable attenuators A1-An odd times and it compounds with mixing equipment 82, a SOUTUSU wave (saw-tooth wave) as shown in drawing 6 can be obtained.

[0064] If this sow TUSU wave is made to impress to the susceptor 55 of the processing room 52, ion bombardment of etchant ion can be strengthened and it is possible to raise an etching rate. In addition, such waveform operation can be carried out with a central control unit 84 and the peripheral device which is not illustrated.

[0065] further -- again -- VCO G1 and VCO G3, and G5 and G7 -- if only a wave is oscillated odd times and frequency modulation of this is compounded and carried out as ... is operated and it was shown in drawing 7 to the fundamental wave, a square wave as shown in drawing 8 can be obtained the above which will be reactant gas by controlling the pulse width if this square wave is impressed to a susceptor 55 and plasma is generated -- it is possible to control the maceration of CF4 gas

[0066] For example, by setting pulse width below to 10microsec., it is the maceration of CF4 gas molecule CF3- of the 2nd step + -F Suppressing by the stage is possible. Therefore, since generating of a superfluous fluorine radical is suppressed, and the etching resistance of protection polymer is not spoiled and maceration is not advanced, generation of C (carbon) which it becomes [C] a deposition and stops etching can also be suppressed. So, it is possible to perform high etching processing of a selection ratio.

[0067] Furthermore, as shown in drawing 9 , the output adjustment is suitably carried out by variable attenuators A2, A7, and A8 with the double-precision wave of a fundamental wave F, a 7 time wave, and a phase as it is about a 8 time wave. the 4 time wave of a fundamental wave F, and a 5 time wave -- an each phase -- 180 degrees -- it can shift -- a variable attenuator A4 and A5 -- the -- if output adjustment is carried out and these are compounded, as shown in drawing 10 , the narrow and unsymmetrical pulse wave of pulse width can be obtained In addition, in the aforementioned power unit 81, since the level change machine 85 is formed in the wide band frequency amplifying device 83, it is possible to obtain such an unsymmetrical pulse wave by the operation of this level change machine 85.

[0068] In addition, as shown in drawing 11 , a standup and falling as shown in drawing 12 can obtain the triangle wave between simultaneous (triangular wave) by oscillating only a wave odd times, and being able to shift 180-degree phase by turns and carrying out frequency modulation of them. According to this triangle wave, it is possible to always carry out incidence of the etchant ion with fixed acceleration. Of course, it is possible not only the above-mentioned wave but to make other waves create by control by the central control unit 84.

[0069] By carrying out frequency modulation to a fundamental wave as mentioned above, combining the integral multiple wave suitably, it is possible by controlling the strength of the ion bombardment or controlling the maceration of a gas molecule further according to the kind of etchant ion of various kinds of reactant gas including CF4 gas molecule as stated above, and mass, to raise an etching rate and to perform high etching processing of a selection ratio to a processed object.
[0070] since what is necessary is just to make it oscillate to the seven to 9 time wave of a fundamental wave in general in order to acquire the predetermined wave for which it asks by such frequency modulation -- the above -- if the VCO prepared in a power unit 81 and the corresponding variable attenuator equip VCO G1-G10 and the about [variable-attenuator A1-A10] number, respectively, it will be convenient practically Moreover, since it ends with small power to a fundamental wave, it is suitable for retrofit reconstruction, and cost is also cheap and can be realized.
[0071] Since acceleration of etchant ion is controllable, of course, it is possible to also make the charge up on Wafer W planned in the 1st example as stated above cancel.
[0072] in addition, the above -- for example, an armature-voltage control filter and a notch filter are made to intervene between mixing equipment 82 and the wide band frequency amplifying device 83, and you may make it modulate the cut off frequency of a filter in a power unit 81 In this case, the operation effect that it can carry out adjustable [of the generating efficiency of etchant and the drawing-in ratio of the ion to an installation base (lower electrode)] is acquired.
[0073] Furthermore, as a mechanism in which the whole DC bias is changed compulsorily, you may prepare the direct-current regulated power supply which cut the high frequency component in either an up impression mechanism or a lower impression mechanism and its both. In this case, the operation effect of the ability to carry out the focus of the etchant on a wafer, or make it emitting is acquired.
[0074] Although the aforementioned power unit 81 had taken the composition which is made to oscillate the integral multiple wave to a fundamental wave, and performs frequency modulation, combining these suitably, it may be replaced with the power unit 81 which has this composition, and the power unit 91 as shown in drawing 13 may be used for it.
[0075] This power unit 91 possesses the plurality K1-K4 which has industrial use frequency and the Wireless Telegraph Law conformity frequency as VCO, respectively, for example, four VCO, and VCO K1 has the composition that 13.56MHz and VCO K3 output 27.12MHz, and VCO K4 outputs a sine wave with a frequency of 40.68MHz, as for 380kHz and VCO K2, for example, respectively. And the output of each aforementioned VCO K1-K4 is inputted into the timing gates T1-T4 which correspond, respectively. These timing gates T1-T4 are constituted by control of a central control unit 92 so that the gate may be opened and closed, and only any one timing gate opens them by it.
[0076] Moreover, the phase at the time of a wave switching by opening and closing of the aforementioned timing gates T1-T4 is amended in the aforementioned central control unit 92, and the phase correction equipment 93 for making this into a continuous wave is formed in it. And by the mixing equipment (or combined-harvester-and-thresher equipment) 94 which mixes an output signal, the signal outputted by opening and closing of each aforementioned timing gates T1-T4 becomes one continuous wave, and through the amplifying device 95 and the blocking capacitor 77, it is constituted so that it may be impressed by the susceptor 55 in the processing room 52.
[0077] If the power unit 91 which has this composition is used, it will become possible to make power with the output wave as shown, for example in drawing 14 impress to a susceptor 55. Namely, although the wave itself is all a sine wave, the frequency changes, for example for every half period or period, and, as for the wave shown in this drawing, height of frequency is realized for every period of this. According to such an output wave, the incidence energy of etchant ion can be controlled very minutely, for example, and control of the etching property in higher level is possible.
[0078] Although the method modulated by the time basis like 1 second and 2 seconds is also considered when performing such frequency modulation for example, since it is very large compared with the dissociation time of a reactant gas molecule, the fall of an etching rate is not avoided for the modulation in this order like previous statement. However, as described above, by modulating this in period, it is the range which does not advance the dissociative reaction and it is possible to control the incidence energy

of etchant ion, to adjust the ion bombardment, and to raise an etching rate. Therefore, it is possible to carry out high etching processing of an anisotropy. And as shown in the graph of drawing 14 , it is also possible to set up Interval P on the way and to stop impression of power, and more detailed control is possible.

[0079] Furthermore, it replaces with the above-mentioned power units 81 and 91, and the power unit 101 shown in drawing 15 can also be proposed. RF generator 102 which this power unit 101 has taken the composition for performing amplitude modulation, for example, sends the frequency of 13.56MHz, The variable attenuator 103 for decreasing an amplitude in the output wave of this RF generator 102, it has the amplifier 104 and the adjustment machine 105 for amplifying the output which passed through the aforementioned variable attenuator 103, and pass this adjustment machine 105 -- the above -- it is constituted so that predetermined RF power may be impressed to the susceptor 55 in the processing room 52

[0080] If amplitude modulation shown in drawing 16 is performed using this power unit 101 and plasma is generated between the up electrode 72 and a susceptor 55, the following plasma control is possible. Amplitude modulation first shown in the graph of this drawing is performed so that the subcarrier (shown by the dashed line in drawing 16) C called envelope which connected the peak of the wave modulated by this amplitude modulation may form an abbreviation trapezoidal wave. And it is set up so that each time of the standup sections A1 and A2 in drawing, flat parts S1, S2, and S3, S4, and the falling sections D1, D2, and D3 may become below 10microsec. (second) in this subcarrier C.

[0081] It starts at least and falls with the section. thus, when amplitude modulation is carried out, it can set to the subcarrier C obtained -- the section Since plasma is generated in the processing room 52 and it etches to the semiconductor wafer W which is a processed object by the wave which becomes below 10microsec. (second) respectively For example, incidence energy can be added to etchant ion and it is possible to raise an etching rate without advancing maceration of this CF4 to a culmination, if it bases and explains when CF4 is used as reactant gas like the above.

[0082] In addition, what is necessary is just to, define the wave and amplification degree of Subcarrier C according to the mass and the kind of etchant ion for [of not only this but a processed object] etching, of course, although Subcarrier C is an abbreviation trapezoidal wave, and amplitude modulation was carried out in drawing 16 so that the waveform characteristic might become linear. For example, it may fall with the standup section in Subcarrier C, and the section may be stair-like. Such the waveform characteristic is obtained by adding a modulation using an A/D converter.

[0083] When amplitude modulation constitutes a subcarrier (envelope) such further again, you may be any of the first rank in an amplification process, an intermediate stage, and a tail end. however, the first rank with a still small output -- near tends to add a modulation In addition, if in charge of the amplification after a modulation, since there is little distortion of an output, the class-A-amplification mode constituted so that the output current might be produced over between the whole term of ac input is more desirable.

[0084] Moreover, even if it uses this power unit 101, it is possible to, prevent the device destruction on the semiconductor wafer W by the charge up as stated above, of course. In addition, the processor with which each of said power units 81 and 91,101 are used is applicable also to the magnetron RIE system used on the occasion of the 1st [not only this but] example, although it was an parallel monotonous type RIE system. Furthermore, a processed object may also be for example, not only the semiconductor wafer like previous statement but a LCD substrate.

[0085]

[Effect of the Invention] According to the claim 1, it is possible to prevent the charge up of a processed object and to prevent destruction of the device by the charge-up phenomenon concerned, without reducing most plasma densities. Moreover, the composition for realizing it can also be applied to existing plasma treatment equipment very simply, and it is possible to take the method of amplitude modulation which also indicated the modulation method in that case to frequency modulation and claims 2 and 7.

[0086] According to the claim 3, when carrying out plasma etching processing, for example, it is

possible to suppress dissociation advance of a gas molecule or to control ion bombardment of etchant ion, and it is possible to raise the selection ratio and to carry out good anisotropic etching.
[0087] Moreover, according to the claim 4, since SOUTUSU waves (saw-tooth wave) including various kinds of arbitrary waves, for example, a pulse wave, a triangle wave (triangular wave), and a RAMUPU wave (ramp) can be made to create easily, it is possible to control the dissociation stage in plasma treatment still more finely, or to control an ion bombardment. Therefore, it is possible to raise an etching rate further.
[0088] Moreover, since it consists of claims 5 so that the reactant gas more concretely introduced into the processing interior of a room may not start the maceration of a culmination in the plasma treatment method of these claims 3 and 4, and frequency modulation may be controlled, neither superfluous etchant ion nor an unnecessary sediment can be generated, and the selection ratio in etching processing can be raised.
[0089] Furthermore, by the claim 6, since it is carrying out for dividing signalling frequency in period and adding frequency modulation, the maceration of the raw-gas molecule introduced into the processing interior of a room in the portion with high frequency can be promoted, or an ion bombardment can be enlarged in the low portion of frequency, and, moreover, high control of a minute precision is attained.
[0090] Moreover, according to the claim 7, based on amplitude modulation, maceration of the gas molecule of the processing interior of a room can be controlled, and it is easy to control.

[Translation done.]